DOCUMENT RESUME

ED 236 016 SE 043 295

AUTHOR Osborne, Roger; And Others
TITLE Force, Friction, Gravity: Notes for Teachers. Learning in Science Project. Working Paper No. 33.
INSTITUTION Waikato Univ., Hamilton (New Zealand).
PUB DATE Nov 81
NOTE 43p.; For related documents, see ED 226 976, ED 229 442, ED 230 594, ED 235 011-030, SE 043 285-302, and SE 043 305-315. Document contains some marginal legibility. Working Paper No. 33 should be used in conjunction with SE 043 294 and SE 043 296.
AVAILABLE FROM University of Waikato, Science Education Research Unit, Hamilton, New Zealand.
PUB TYPE Reports - Evaluative/Feasibility (142) -- Reports - Research/Technical (143) -- Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Comprehension; *Concept Formation; Concept Teaching; *Curriculum Development; Elementary School Science; Elementary Secondary Education; *Force; Gravity (Physics); Interviews; Learning; Physics; Science Activities; Science Education; *Science Instruction; *Secondary School Science
IDENTIFIERS *Learning in Science Project; *New Zealand; Science Education Research

ABSTRACT

This booklet provides teachers with background information on typical children's and scientists' views of force, friction, and gravity. Part 1 presents and discusses a survey instrument designed for teachers to use to clarify their views on the topics. Part 2 contrasts (in chart format) children's and scientists' ideas on the concepts. Parts 3 to 5 present and discuss the scientific view of and children's views of force, friction, and gravity, respectively. Included are students' comments and highlights of surveys conducted during the in-depth phase of the project investigating problems/difficulties in teaching and learning about the three concepts. Implications for teaching are also considered, suggesting that if teachers wish to modify children's views to make them more scientific, there is a need to focus children's attention very clearly on the differences between their views and the scientific viewpoint. Instructional materials have been developed using this approach. (Cards used during in-depth phase interviews to investigate children's views of force are included in an appendix.) (JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED236016

LEARNING IN SCIENCE PROJECT

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

✓ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

FORCE, FRICTION, GRAVITY:

Notes for teachers

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY
Roger Osborne
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

University of Waikato
Hamilton, N.Z.

SE043295

WORKING PAPER No. 33

FORCE, FRICTION AND GRAVITY - NOTES FOR TEACHERS

Roger Osborne, Brendan Schollum and Graham Hill+

Learning in Science Project,

University of Waikato,

Hamilton, New Zealand.

November 1981

CONTENTS

		Page
Introduction		1
PART 1	Investigating your own views about force, friction and gravity	2
PART 2	Contrast between children's ideas and scientists' ideas (a summary)	10
	2.1 Force	
	2.2 Friction	
	2.3 Gravity	
PART 3	Force	13
	3.1 The scientific view of force	
	3.2 Children's views about force	
PART 4	Friction	20
	4.1 The scientific view of friction	
	4.2 Children's views about friction	
PART 5	Gravity	27
	5.1 The scientific view of gravity	
	5.2 Children's views about gravity	
Implications for teaching		37
Appendix A:	The interview cards on force	38

+ These notes are a condensed and modified version of the working papers Force, by Roger Osborne; Friction, and Gravity, by Keith Stead; - Working papers of the L.I.S.P. in-depth phase (No. 16, 19, 20). Thanks also to A. Zylberstein, I.E.T., University of Surrey, for ideas leading to Q.1-3 of the Survey.

INTRODUCTION

> "Many times my physicist friends have attempted to explain a concept to me and, in their exasperation, have tried one explanation after another, each one of which sounded (to me) abstract, difficult to grasp, and generally abstruse. When I could comprehend, at last, what they were trying to communicate inevitably I was surprised to discover that the idea was actually quite simple."
>
> (Zukav, 1979, p. 24)[1]

Some of the key ideas in physics seem to cause great problems for pupils trying to learn science. To physicists, the concept of force is a simple idea and one of central importance in understanding how and why things behave as they do. Yet to the learner of science, it is not simple at all.

> "The only thing we had which I didn't really understand was the physics sort of things ... you know, like the ball rolling up the hill and coming down again ... I just sort of got lost."
>
> (ex-pupil)

Sometimes it is not simple to teachers either!

> "The topic force is sort of covered (by us) but if you asked a physicist to look at what concepts were developed I am not sure he would say that they are very good at all."
>
> (intermediate school teacher)

And it certainly isn't easy to teach in the opinion of a number of teachers. For example,

> "I feel I need time and resource materials and help from a physics minded person to help with that particular topic ... especially at the Form 3 level ... it is trying to get it across in a simple enough way that they would understand it and enjoy it."
>
> (secondary teacher)

Even when the teaching is finished it is not always clear what they have learnt,

> "I sometimes wonder how much is being attained in understanding what forces are ... it is difficult to know whether kids are understanding them or not."
>
> (secondary teacher)

---

1 Zukav, G. (1979) The Dancing Wu Li Masters. London: Rider/Hutchinson

In our view, to teach ideas about force, and the related notions of friction and gravity successfully then it is necessary for you to know three things;

i) what physicists mean by the terms force, friction and gravity

ii) what children typically mean by the terms force, friction and gravity, and, more importantly,

iii) what your views are of force, friction and gravity and how these views compare with i) and ii) above.

In this paper we explore these viewpoints.

PART 1: INVESTIGATING YOUR OWN VIEWS

We start by considering your own views of force, friction and gravity, and compare these with a physicists viewpoint. Try the seventeen questions in the Survey that follows. We have found that the Survey does help teachers to clarify their views on force, friction and gravity. We believe you the teachers, will get the most out of this booklet if you first answer all the Survey questions youself. If necessary rely on your intuition, i.e. what you think is natural, and what makes sense to you. That's what you often have to do when you get an awkward question in class! Write down your answers on a sheet of paper as you proceed.

When you have finished the Survey compare your answers with those provided on pp. 7 and 8. Don't worry if your answers are considerably different - many teachers find this! If you wish to test your ideas further you can attempt to answer the interview cards in the Appendix, (pp. 38 - 40) covering up the Physicists' viewpoint provided.[2]

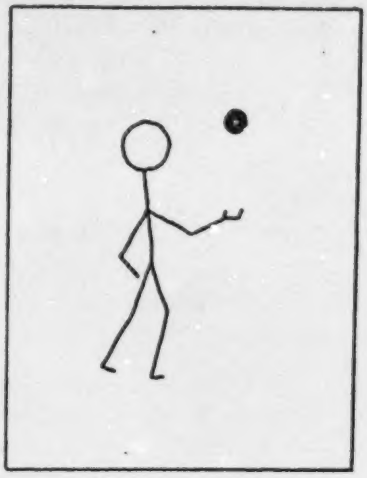
---

2 You will often find references made to other parts of the paper. These can direct you to further explanations, or to furthr examples of the idea being discussed. The references enable you also to relate the survey questions and answers to different parts of the paper.

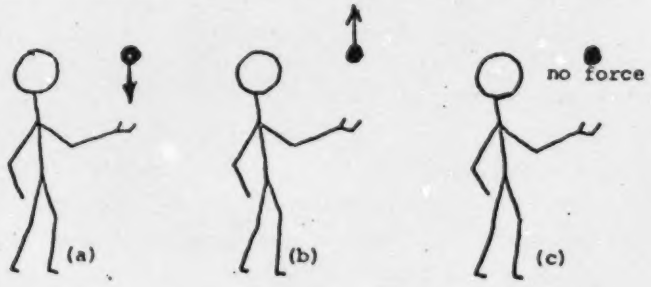
1.1 Survey for Teachers on Force, Friction and Gravity

Q.1-3 A person throws a tennis ball straight up into the air just a small way.

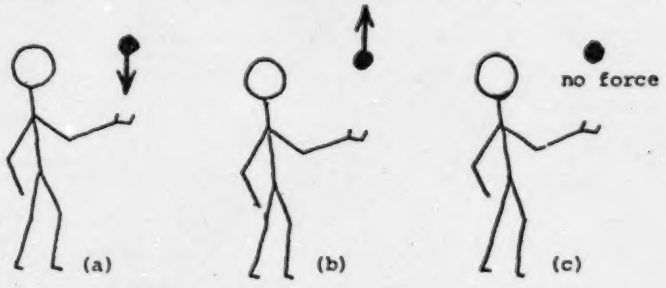
The questions are about the total force on the ball.



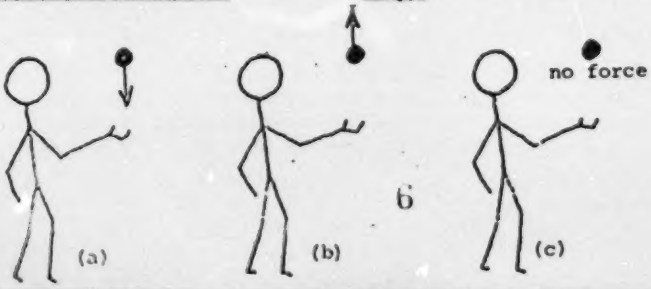
Q.1 If the ball is on the way up, then the force on the ball is shown by which arrow?



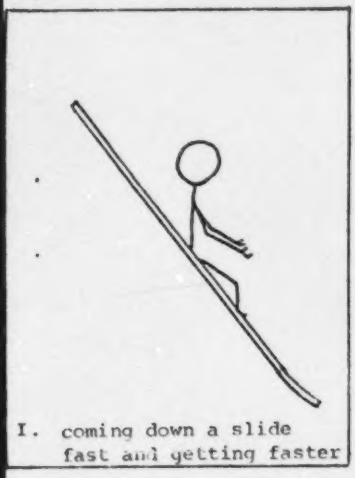
Q.2 If the ball is just at the top of its flight, then the force on the ball is shown by which arrow?



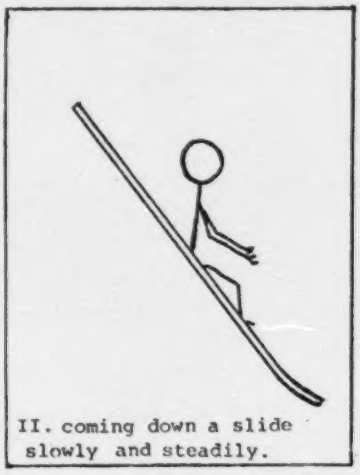
Q.3 If the ball is on the way down, then the force on the ball is shown by which arrow?



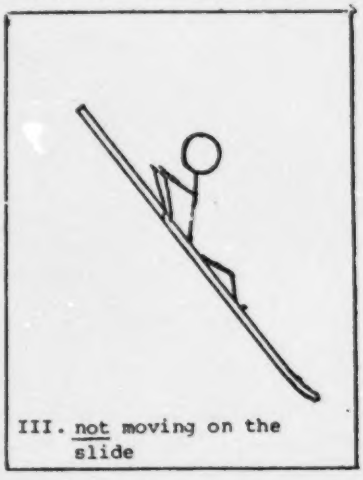
Q.4-7 A person is playing on a slide. The pictures show what was happening at three different times. The questions are about friction between the person and the slide.



I. coming down a slide fast and getting faster



II. coming down a slide slowly and steadily.



III. not moving on the slide

Q.4 Look at picture I only. Would there be any friction? (a) Yes (b) No

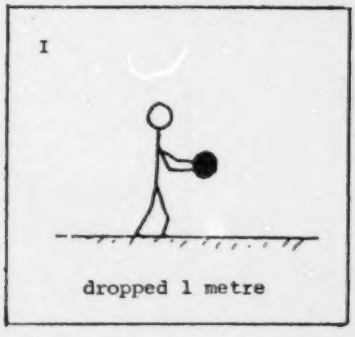
Q.5 Look at picture II only. Would there be any friction? (a) Yes (b) No

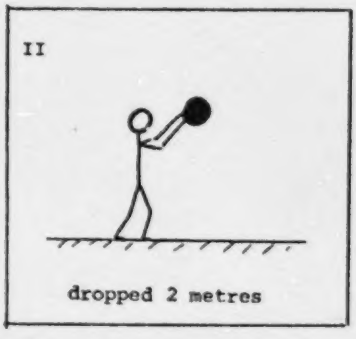
Q.6 Look at picture III only. Would there be any friction? (a) Yes (b) No

Q.7 Look at pictures I and II only. In which of the two pictures is there more friction?

(a) More in I
(b) More in II
(c) The same in I and II
(d) There is no friction in either I or II

Q.8 A ball is dropped from different heights onto concrete.

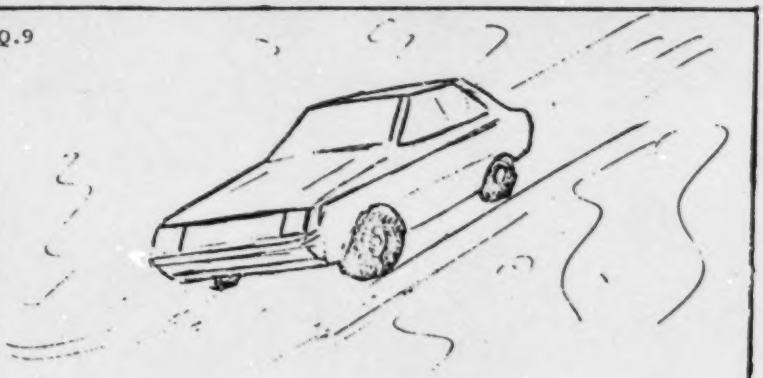




The ball drops straight down and is not spinning. When the ball hits the concrete the friction between the ball and the concrete will be

(a) greatest in I
(b) greatest in II
(c) the same in both cases but not zero
(d) zero in both cases

Q.9

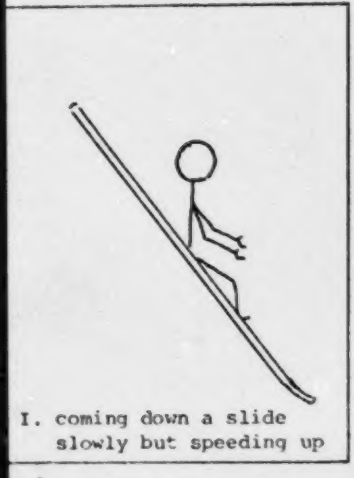


coming down a long hill the car brakes get hot

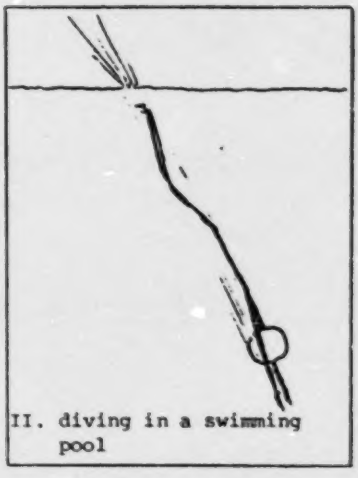
The energy coming out of the brakes is

(a) heat
(b) friction
(c) gravity
(d) magnetic

Q.10-12 These questions are about whether there is any friction on the person.



I. coming down a slide slowly but speeding up



II. diving in a swimming pool

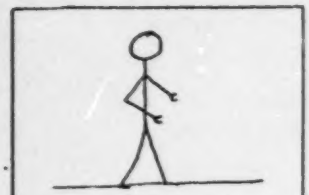
III. sky diving from a plane

Q.10 Look at picture I only. Would there be any friction? (a) Yes (b) No

Q.11 Look at picture II only. Would there be any friction? (a) Yes (b) No

Q.12 Look at picture III only. Would there be any friction? (a) Yes (b) No

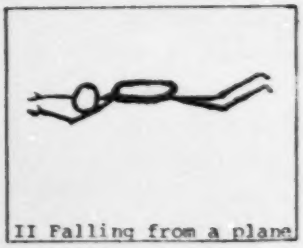
Q.13-17 These questions are about whether or not there would be gravity in different places.



I Standing on the earth

Q.13. Look at picture I. Is there any gravity when you are standing on the earth.

(a) Yes
(b) No



II Falling from a plane

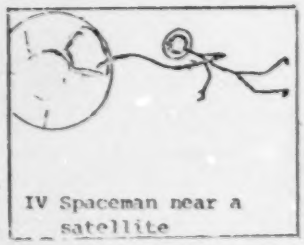
Q.14. Look at picture II. Is there any gravity?

(a) Yes, about the same as on the ground
(b) Yes, but much less than on the ground
(c) Yes, but much more than on the ground
(d) No, there is no gravity

III Standing on the moon

Q.15. Look at picture III. Is there any gravity?

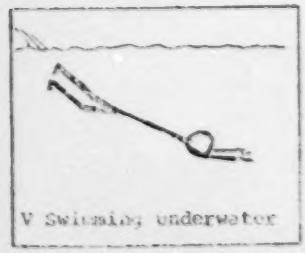
(a) Yes, but much more than on the earth
(b) Yes, about the same as on the earth
(c) Yes, but much less than on the earth
(d) No, there is no gravity



IV Spaceman near a satellite

Q.16. Look at picture IV. The satellite is going around the earth. Is there any gravity up where the spaceman is?

(a) Yes
(b) No



V Swimming underwater

Q.17. Look at picture V. Is there any gravity when the person is swimming underwater?

(a) Yes
(b) No
(c) Depends on whether the person is going up or down.

1.2 A Physicist's Answers to the Survey Questions

Q.1-3 (a-a-a) A force is an external push or pull acting on an object. In this case there is only one significant force on the ball, the force of gravity, which is a constant force acting on the ball at all times in a downward direction. Its effect is to slow down the ball moving upwards until it becomes momentarily stationary. Even at that instant, the force of gravity acts. Since the force (pull) continues to act, the ball falls, speeding up as it does so. (Another force, that of friction between the ball and the air, acts on the ball opposite to the direction of its motion, while it is moving. In this example the speeds reached are not large. Hence friction will be negligible compared to gravity, and will not significantly affect the ball's motion). As we will see later, physicists do not consider there is always a force in the direction of the motion.

Q.4 (a) There would be some force of friction on the person by the slide. The direction of the force of friction would be opposite to the direction of motion. Also acting are reaction and gravity forces. The force of gravity is vertically downwards i.e. towards the centre of the earth. The reaction force is at right angles to the surface. Refer to Appendix (BOX and BALL) for more information about these forces.

Q.5 (a) In this case the force of friction would be greater than in the situation considered in Q.4. As the person is moving down slowly and steadily the total force on the person would be zero, i.e. the sum of the friction forces, the reaction force and the weight force would be zero as there is no change in speed (see p. 14).

Q.6 (a) This is an identical situation, with respect to the forces now on the person, to the situation in Q.5. As there is no change in speed (see p. 14). Suitable diagrams showing the directions of these three forces can be seen on p. 39 (BOX and BALL rolling down slope). The commonly held,

but unscientific view, that friction is present only when heat or movement are experienced is incomplete. Refer to Part 2.2 on p. 11.

Q.7 (b) There is more friction in situation II than in situation I. In situation I there is insufficient friction up the slide to be equal and opposite to the sum of the reaction and gravity forces in the opposite direction (see p. 39).

Q.8 (d) The frictional forces on the ball with the ground will be negligible. Certainly the total frictional force will be zero since there is no tendency for the ball to slide or move sideways while in contact with the ground. The force acting on the ball from the ground is a reaction force. Refer to footnotes 18 and 19, p. 24.

Q.9 (a) Heat is one form of energy being transferred. Friction is a force not a form of energy, so answer (b) is not scientifically correct. Heat can be a consequence of the force of friction acting (in this case, between brakes and brake drums). Sound can be another effect.

Q.10-11(a-a-a) Friction can occur between any combination of solids, liquids and gases. Friction occurs when one substance tends to oppose the movement of another through or over it. In Q.11, the force of friction acts upwards as the person is diving downwards through the water. Other forces present are the buoyancy force acting upwards at all times, and the force of gravity acting toward the centre of the earth at all times. The gravity force is the same value whether the diver is above, or below, the water surface, but the buoyancy effect in air is much less than in water.

Q.13 (a) The force of gravity is always toward the earth's centre. If there was not an equal force in the opposite direction the person would fall below the surface of the earth. (This happens when a person stands on thin ice!) Reaction force is the name given to the force opposing the force of gravity in this case. A reaction force acts perpendicular to a surface; its a sort of buoyancy force!

Q.14 (a) The force of gravity would be almost exactly the same value at all positions between the plane and the ground. (See footnote 21, p. 27)

Q.15 (c) The pull of gravity by the moon at the moon's surface is about one-sixth of the pull of gravity by the earth at the earth's surface. This is because the moon is considerably smaller than the earth. (Refer to Part 5.1, p. 27)

Q.16 (a) The pull of gravity by the earth on the man and the satellite is causing the man and satellite to circle the earth, rather than travel in a straight line away from the earth. However they continue to move in a circular orbit because they are moving at such a high speed (8 km/sec is typical for a spacecraft 320 km above the earth's surface), that they "fall" at the same rate as the horizon of the earth's surface curves. The spacecraft and man continue to orbit the earth as they fall. Newton was one of the first people who thought about this in the way that scientists now think about it.

<u>Newton's thought experiment</u>

A body is thrown from a high mountain at various speeds. At a certain speed (very fast) the object "falls" at the same rate as the curvature of the earth.

Q.17 (a) The pull of gravity on the swimmer is the same as when she is above the surface of the water. The upward force on the swimmer is called a buoyancy force, rather than the term reaction force which is used for the upward force on a person standing on solid ground.

PART 2: THE CONTRAST BETWEEN CHILDREN'S IDEAS AND SCIENTISTS' IDEAS (A SUMMARY)

As we shall see as we work through this paper children (and many adults!) have strong views about force, friction and gravity, but they differ from the scientists' viewpoint. The view of children* and those of scientists for each of the topics FORCE, FRICTION and GRAVITY are summarised below. These views are explained in greater detail in Parts 3, 4 and 5 which follows. If children have non-scientific views we can look upon teaching science as helping children modify their views towards the scientists' view, or at least appreciate the scientific viewpoint.

2.1 Force

Children's[4] Science ⟹	needs changing in terms of the scientist's meaning of force	⟹ Scientists' Science
Force is making someone do something against their will. (p.15)	Force is <u>not</u> making someone do something.	Force is a push or pull.
Force is a thing <u>in</u> a moving body (e.g. a moving golf ball. (p.16-17)	Force is not a thing in a body; it acts <u>on</u> a body.	A moving body has <u>momentum</u>. The faster it moves the greater the momentum.
There must be a force on, or in, a body moving at a steady speed. (p.16-17)	If a body is moving at a steady speed there is <u>no</u> total force acting on it.	The <u>total force</u> on a body, moving at steady speed, is zero.
Force is a thing put into a body causing it to move. (p.16-17)	If a force is acting on a body, then something is pushing or pulling on the body.	Force on one body means there is an opposite force on another body.
Force is a change of position. (p.17)	Force is only indirectly a change of position.	Force is a change of momentum (or speed or velocity.
Force is the same as momentum. (p.17)	Force is not equal to momentum.	Force is the rate of change of momentum.

---

3 Not all of the children's ideas are held by all children. However, it is likely that any particular idea will be held by at least a few children in your class. Further information on any particular view is to found at the page referenced.

4 By children's science we mean the views of the world and meanings for words that children hold prior to formal science teaching, and often retain despite scence teaching.

2.2 Friction

Children's Science ⟹	needs changing to ⟹	scientists' science
Friction is rubbing, causing heat and wearing. (p.21)	Friction can exist without surfaces wearing or heating up.	Friction is a push, or a pull. (a sort of holding force).
Friction forces include pressure (or reaction) forces. (p.24)	Friction forces are <u>not</u> pressure or reaction forces.	Friction forces are holding forces <u>along</u> surfaces.
Friction does not occur if there is no movement between surfaces. (p.22)	Friction <u>can</u> occur even if there is <u>no</u> movement between surfaces.	Friction forces can be present between surfaces that are not moving.
Friction is in the opposite direction to the direction of motion.	Friction is <u>not</u> always associated with movement in the opposite direction.	Friction forces can be in the same or the opposite direction to the direction of motion.[5]
Friction only occurs between solids. (p.26)	Friction is not just between solids.	There can be friction between any combination of solids, liquids and gases.

[5] For example in the case of a self propelled object, a person walking or a car accelerating, frictional forces, <u>in the direction of motion</u>, are producing the forward acceleration. Also there can be frictional forces present when there is no motion at all.

2.3 Gravity

Children's science ⟶ needs changing to ⟶ scientists' science		
Gravity is a push. ((p29)	Gravity is a pull rather than a push.	Gravity is a pull.
You can have weight without gravity. (p.30)	You cannot have weight without gravity.	The pull of gravity is called weight.
Gravity holds things up, or acts upwards at the earth's surface. (p.31)	Gravity does not hold things up, nor acts upwards, at the earth's surface.	Gravity is pulling all things on or near the earth toward the centre of the earth.
Gravity can be reduced in liquids (or solids of gases). (p.31)	Gravity is <u>not</u> reduced in liquids (or solids or gases), there are just other opposite forces acting (e.g. buoyancy forces, reaction forces).	Gravity is a force that acts "through" solids, liquids, or gases (for example a springboard diver has the same force of gravity on her at all times, whether above or below the water surface.
Gravity is only present when air is present. (p.34)	Gravity can still be present even when no air is present.	The pull of gravity can act through a vacuum.
Gravity increases with height above the earth's surface. (p.33)	Gravity does <u>not</u> increase in height above the earth.	The earth's pull of gravity decreases slowly with height above the earth.
Gravity is absent above the atmosphere. (p.34)	Gravity is <u>not</u> absent above the atmosphere.	The earth's pull of gravity still acts above the earth's atmosphere.
Gravity is zero on the moon. (p.35)	Gravity is <u>not</u> zero on the moon.	Any large object attracts other objects toward it. We call this attraction <u>gravity</u>.
Gravity is caused by the earth spinning. (p.37)	Gravity has really nothing to do with spinning.	The pull of gravity between any two objects depends only on the mass of the object and their distance apart.
Gravity is a substance.	Gravity is not a substance.	The pull of gravity is very mysterious. No one really knows what it is.

PART 3: FORCE

3.1 The Scientific View of Force

Basically to a physicist, forces are synonomous with pushes and pulls. If you push on a box you put a force on the box - "apply a force to the box" - not in the sense of giving it a 'material' something but simply in the sense of the noun push - the "act of pushing". If you pull on a box, then there is a force on the box simply in the sense of the act of pulling. If a golf ball is hit from a tee there is a force on the ball while the club head and the ball are in contact. No force is transferred to the ball. Once the hit is finished and the ball leaves the club there is no force on the ball, or in the ball, from the hit as the club no longer pushes on the ball. The impact is completed.

To a physicist there is a force acting on an object if there is some external agency pushing or pulling on the body. Each push, or pull, will have a certain strength - large push or small push - and will be in some direction. The external agency applying the force can be living e.g. a person pushing a car or non-living e.g. friction, gravity. The clear difference between the physicist's view and many children's views of force is that to a physicist a force acts on objects rather than being contained within objects.[6]

If all pushes and pulls involved contact, so that the object producing the push or pull was clearly apparent, then it would perhaps be not too difficult for children to understand the physicists' idea of a force. Unfortunately many forces are very mysterious to everyone, including physicists, in that pushes and pulls can occur without contact and are not just applied by living things. The earth pulls all other objects

---

6 Children's intuitive idea of force being in a body in the direction of motion (see later) is quite similar to the physicists' concept of momentum; except that to a physicist, momentum is not considered a force. (Momentum = mass of a body x velocity of the body.) Force is related to changes in momentum.

towards it, physicists don't know how this occurs - the force of gravity is a mystery.

To some extent physicists have stopped concerning themselves too much about what forces, like the force of gravity, actually are. Rather they find it useful to consider them as somewhat mysterious pushes and pulls. They are more interested in measuring the strength of these pushes and pulls, and the effects of these pushes and pulls on objects and on the motion of objects.

What is most important to realise is that in many situations there are a number of pushes or pulls acting on an object at the same time - see Appendix A for examples - and physicists distinguish between individual forces and total force acting on a body.[7] How the motion of a body changes with time is influenced by the total force acting on it; for example, if an object is at rest (for more than an instant) then the total force acting on it is zero.[8] What is a much more difficult idea to understand - and this is where scientists' science differs considerably from children's science - is that an object moving at a steady speed in a straight line also has a total force acting on the object which is zero. This is difficult for children to understand partly because they often have the idea that a moving object has a force in it, and partly because in their experience all the moving objects that they are familiar with appear to require a force acting on them to keep them moving at a steady speed. However a spacecraft needs no pushing to keep it moving through space at a steady speed; an ice puck needs no pushing, once it has been pushed by the ice hockey stick, to

---

7 In this sense the questions of Appendix A are ambiguous. Hence the two physicists' views provided in each case. It is also important to realise that in determining the total force the directions of the individual forces are important. Two equal and opposite forces produce a zero total force.

8 A ball thrown upwards may be at rest for an instant at the top of its flight. However, there is still the pull of gravity on it, and the total force on it is not zero. The ball is changing speed even though the speed may be zero for an instant.

keep it moving in a straight line. From a physicist's view point a box sliding on a surface needs a steady push to keep it moving, at a steady speed, not because the force inside it is 'wearing out' and needs to be replaced as some children view it, but rather to provide a force equal and opposite to the force of friction which is pushing in the opposite direction. In fact physicists use this idea to measure forces; namely if an object is moving at a steady speed (including zero speed) then the total force acting on it is zero. Alternatively if the total force on an object is not zero then it will be changing speed (e.g. an apple falling), or changing the direction of the speed (e.g. a ball whirled around your head on the end of a string) or both.

3.2 Children's Views About 'Force'

Here, we consider some typical views of children related to the idea of force. The information provided comes from an analysis of interviews with a range of children and older students who were individually questioned about the interview cards of Appendix A.[9] Where applicable we will also consider typical pupil responses to questions given in the survey.

The word force, while having a technical meaning in physics is used in a variety of ways in everyday language. Firstly, as an organised body of people e.g. the police force. Only once in the set of interviews was it used in this way.

Secondly, it was more commonly used by children as a verb. For example,

> "Yes, because he is being forced to do something."
> (Police, Std. 3, 2 x P1, P3)[10]

---

9 38 students were interviewed ranging from Std. 3 (age 9) to teachers College students (7 x Std. 3, 9 x F1, 10 x F3, 5 x F5, 7 x T). All school pupils were studying science. Teachers college students who have studied school certificate science, U.E. Physics, U.B. Physics are designated T(SC), T(E) and T(B) respectively. Each interview session was audio taped and the tapes were later transcribed and analysed.

10 Name denotes instance, see Appendix A. Numbers denote level of children with that view.

"Yes, he is trying to force it to go."
(Car I, 2 x F3, T(SC))

This everyday use of the word force as a verb, to force, is very much related to human experience and consists of two distinct types, physical contact and mental coersion. The instances and the associated questions were quite commonly considered by children from this human-centred viewpoint. Examples are,

"No, he is just relaxing."
(Police, Std 3)

"Yes, he is going without his will."
(Police, 4 x F3)

This human-centred view was particularly common with the accelerating car instance (Car II) even though the diagram did not show the driver.

"Yes, the man is putting a force on the car."
(Car II, 3 x F3, T(SC))

"No, because no one has to push it."
(Car II, Std 3, 2 x F1)

These everyday language and human-centred viewpoints are closely related to the view that if there is no obvious external agency forcing the body then there is no force on the body.

"No, it's just dropping freely."
(Golf II, 2 x Std 3, 2 x F1, 3 x F3)

"No, it just naturally rolls down."
(Ball, F3)

Another aspect of the human-centred viewpoint is the idea that something that can't be observed or felt by humans (or animals) doesn't exist This view is quite commonly held by children, for example

"No, the golf ball can't feel anything ... it is just made."
(Golf, Std 3)

"I don't know, the car has not got a brain or anything."
(Car I, F1)

In a number of concepts that we have studied children not only often have rather human-centred or even self-centred viewpoints, but also they attribute many of the characteristics of humans or animals to non-living things - for example, forcing oneself to do something. Endowing objects with human or animal characteristics is seen in many examples;

> "Yes, it is forcing itself to stop."
> (Bike, Std 3)

> "I suppose there is a bit of force because it has got to force itself to stay up."
> (Box, Std 3)

Related to this viewpoint is the idea that forcing oneself to do something requires action. This it is not surprising to find that many children endow moving objects with a force. For example,

> "Yes, the speed that has already got up."
> (Bike, T(SC))

and the negative examples,

> "No, because he cannot get it to move."
> (Car I, F1)

Moreover, as with other concepts, we found examples of the abstract idea being treated as if it had material existence; the force is somehow imbedded in the moving object,

> "Yes, because the man would be hitting (the ball) and there would be a force on the ball (which) would be getting less as it goes up."
> (Golf I, 3 x Std 3, 3 x F1, F3, F5)

> "The force from when the bowler let it go would still be inside it ... it has not finished."
> (Bowl, T(SC), T(E))

This view of force, as something in a moving object, is a widely held view. It is not the way physicists now think about force (although the Ancient Greeks had a similar view). However, some tertiary students of

physics still have this view despite considerable exposure to physics teaching.[11] The following tertiary student had done seventh form physics!

> "There is a force because of the bike's own mass ... the mass of the bike has come to such a speed that it won't just stop straight away ... the force is still in there ... in the bike ... the force was transferred from the person pedalling ... and it is now still adherent in the bike ... the bike still moves forward."
>
> (Bike, T(B))

The language of the above quote is sophisticated, but the underlying idea is the same as that held by many younger children.

Questions 1-3 of the Survey (see p. 3) were specifically designed to find out the prevalance of the force <u>in</u> a moving body idea amongst students. Students with this "Greek" view will answer b-c-a respectively to the three questions rather than the physicists' responses which are a-a-a. The following table shows just how tenaciously held the "Greek" view is, and how difficult it is to change that view.[12]

It should not be overlooked that many children, some 30% of the interview responses, are reasonably conversant with the scientists' idea that essentially a force is simply a push or a pull. This viewpoint can

---

11 Some children who have been taught some physics, see little difference between force, kinetic energy and momentum. To a physicist kinetic energy and momentum are not alternatives to the word force: force acts on a body changing its momentum, while momentum, and kinetic energy, are properties associated with a moving body. In this latter sense the physicists' view of momentum, in particular, is not much different to one aspect a typical child's view of force.

12 The Survey results were obtained from a full range of abilities in co-ed and single sex state schools (7 schools); 3-5 form students were studying Science, 6-7 form students were studying Physics. The alternative which would be the consensus view of the physicists is underlined.

RESULTS AS PERCENTAGES FOR SURVEY QUESTIONS 1-3[13]

	3rd form (N = 254)	4th form (N = 195)	5th form (N = 174)	6th form (N = 147)	7th form (N = 75)
bca	46	53	66	53	52
baa	14	11	9	4	1
bba	4	1	1	-	-
<u>aaa</u>	5	11	6	22	19
aca	9	5	5	14	21
acb	11	10	10	7	7
(other)	11	9	3	-	-

be included here under children's science[14] as it is a view held by some younger children as well as by older children. That is, some children hold this view before being taught any physics.

> "Yes, because something is trying to slow it down ... because something is pushing it the other way it slows down."
>
> (Bike, 2 x Std 3, F5)

> "Yes, the force of gravity and possibly air."
>
> (Golf II, Std 3, F1, F3, T(SC))

Finally, if children are to understand important ideas in physics it is essential that many change thier ideas about force. We believe this can be done, and suggest that the earlier it can be done the better;

13 The underlined response in each of the survey results is the accepted scientific view.

14 The various views discussed in Part 3.2, while exemplified by the interviews about force, are not exclusive to this one concept. Our studies over a variety of concepts show that children are often influenced by the everyday use of the word, in this case, force; they tend to have a rather human-centred view of the world; they tend to endow objects with human characteristics; and they tend to endow abstract ideas with an almost material existence.

before a child's framework of ideas becomes inflexible. The activities booklet "Teaching About Force" LISP Working Paper No 34 suggests how this might be done with children as young as 11 years old. However it cannot be done is isolation from ideas about friction and gravity. We will now consider these two words.

PART 4: FRICTION

4.1 The Scientific View of Friction

Friction to a physicist normally is an abbreviation for 'the force of friction', a force which tends to oppose the sliding of one material over another.[15] If two surfaces have no tendency to slide, for example the surfaces of a box and a table when the box is sitting on the table, there are no frictional forces present. However if two surfaces have a tendency to slide, for example because the table is not level, a frictional force will normally be present whether or not the surfaces are actually moving. The frictional force will be along the surface, in a direction which opposes the tendency to slide or the sliding. (For example consider the physicists' view of the situation in Appendix A. In addition to frictional forces along the surfaces in contact, there are normally non-frictional forces called reaction forces present. Reaction forces are at right angles to the surface. (To clarify these ideas consider the physicists' view in Appendix A).

4.2 Aspects of Children's Views About Friction

Information on children's views was obtained from individual interviews in which a set of 10 illustrations each mounted on an individual card

---

15 The exact nature of this force, which is a combined effect of forces at the molecular level between the two materials is very complex. It must be remembered the frictional force opposing the tendency to slide is not always in the direction of motion, the frictional forces on the man's foot in Appendix A Car II, are both in the direction of motion of the 'self-propelling' man and car respectively.

(See Figure 1) were used to provide a focus to discussion about the idea of FRICTION.[16]

(Card No 1)

(Card No 5)

(Card No 3)

Figure 1: Three of the cards used in the interviews.

One of the main features of the children's responses was that the majority of those interviewed closely associated friction with rubbing, particularly the rubbing of two solid surfaces. Approximately 50% of the Form 2-6 pupils specifically mention 'rubbing'. Unfortunately however, the everyday association of rubbing with movement, wear, heat, pressure between surfaces leads to a number of non-scientific views about friction as we shall see.

(a) Friction and Force

Some pupils (F2, F3, 3 x F5, 2 x F6) had a reasonably sound scientific view of friction as a force and could make that explicitly. For example,

> "Friction is about two forces opposing each other."
> (F5)

---

16 38 students were interviewed from Form 2 to Form 6 (9 x F2, 12 x F3, 9 x F4, 4 x F5, 4 x F6) from 5 different schools. As a follow up study, the prevalence of certain views identified through the interview work was established using survey techniques.

"It's a force between two objects and friction acts in the opposite direction."

(F6)

Other pupils (3 x F2, 2 x F3, F5, F6) viewed friction as a force but had some difficulty stating this explicitly.

"I think it is a force ... I am not sure."

(F4)

"(It's) a resistance between two surfaces ... It's sort of undefinable."

(F6)

Others (2 x F2, 2 x F3, F4) seemed to consider it a kind of force, as determined by their responses to the cards, but were unable to state this explicitly.

(b) Friction and Movement

A not unusual view held by all age groups (4 x F2, 5 x F3, 6 x F4, F5, F6) was that friction was associated with movement. If there was no movement then there was no friction.[17]

In addition to the following Form 3 pupils' views, four Form 4 pupils had similar views.

(Card No. 7) ("We've got a boy coming down a slide here any friction in that scene?") "Yes." ("Where abouts?") "Oh - down the back of his legs and where he's rubbing against the steel or wood on the slide, and on his hands where he's holding on there." ("And what say he stops - actually stops moving - what about the friction then?") "It would decrease it - yeah, decrease it." ("Would there be any friction when he stopped? When he's holding on very tight?") "No."

(F3)

In addition to the following view held by a Form 4 pupil, two other Form 4 pupils and a Form 2 pupil held similar views.

---

17 This idea is bound up with the commonly held child's view (discussed earlier) that any force must necessarily be associated with movement.

> (Card No. 5) (" ... So, there's friction under the foot that slipped?") "Yeah." ("What about the other that's standing firm? Is there friction there?") "No, because it hasn't actually moved or anything."
> (F4)

Friction was almost the movement itself to a few students. For example;

> "(Friction is) how fast things do ... rub against each other. Like sandpaper rubbing against a piece of wood causes friction." ("And exactly what is friction?") "How fast you are going." ("It's to do with speed?") "Yes."
> (F3)

The idea of more friction with greater movement leads to ideas about more friction if something slides further. For example,

> (Card No. 1) (" ... If that car is sliding on, say, ice, is there much friction, or is there no friction?") "Be quite a bit of friction." ("What say it's sliding on tarseal would there be more friction or less?") "Less".
> (F4)

Survey questions 4-7 (see p. 4) indicate how children strongly associate friction with movement. The prevalence of the set of responses 'aab' to the first three questions and the prevalence of response 'a' to question 7 show that there is a very strong link in children's minds between friction and movement.

RESULTS AS PERCENTAGES FOR SURVEY QUESTIONS 4-7

Q.4-6	3rd form (N = 252)	4th form (N = 201)	5th form (N = 179)	6th form (N = 147)	7th form (N = 74)
aab	68	71	54	36	26
abb	8	4	1	-	-
baa	8	5	3	5	5
aaa	10	15	35	56	69
other	8	7	8	3	-
Q.7	(N = 255)	(N = 201)	(N = 176)	(N = 147)	(N = 75)
a	56	53	40	24	13
b	33	35	50	66	80
c	11	11	8	10	7
d	1	1	2	-	-

(c) Friction and Reaction

In our view, one of the difficulties in teaching senior physics is establishing clearly in students' minds the difference between reaction forces[18] and frictional forces.[19] It is not surprising, therefore, to find students who associate friction with what physicists would call a reaction force (3 x F2, 3 x F3, 2 x F4, F5, F6). For example,

> "There is friction only when the parachutist hits the ground."
>
> (F3)

> "Um, like we've got friction now. I'm sitting on a chair and ..." ("Well, as you're sitting still on that chair, have you got any friction on you anywhere?") "Yeah, I'm opposed to the floor."
>
> (F5 girl)

To gain some indication of the percentage of pupils who are confused between reaction and frictional forces, the Survey question (see p. 4) was used. While the results are not unequivocal, they provide no real indication that pupils clearly distinguish between frictional and reaction forces.

RESULTS AS PERCENTAGES FOR SURVEY QUESTION 8

	3rd form (N = 258)	4th form (N = 200)	5th form (N = 179)	6th form (N = 147)	7th form (N = 75)
a	11	10	4	5	3
b	64	52	49	51	35
c	15	27	29	24	27
d	11	12	18	20	36

18 A reaction force supports an object that has gravity acting on it, but which is not falling freely, e.g. a box on a table; the table provides an upward reaction force to counter the downward weight of the box. If the surface cannot provide sufficient reaction force to support the box, then the box will fall through the surface.

19 As exemplified in Appendix A, to a physicist the direction of the reaction forces are at right angles to the surface while the direction of the frictional forces are along the surface.

(d) Friction and Energy

Friction was closely identified with energy, particularly heat energy, by some pupils (F2, F3, 3 x F4, F5). If friction is associated with rubbing and movement this is not surprising.

> "When two things rub together it causes friction." ("What exactly is friction?") "Energy."
> (F4)

and later,

> "It's the energy that comes from something moving.
> (F4)

On the other hand we found two young pupils who differentiated between movement, friction and heat. The following pupil considered there was a friction force on someone stationary on the slide. Later she suggested that friction creates heat:

> ("So friction somehow makes heat?") "Yeah, it can." ("It can, but not always?") "No." ("Can you give me an example of when it might not make heat?") "Um, when you go down a slide you don't make heat if you stop yourself on the slide."
> (F2)

The large number of pupils who chose answer (b) to Survey question 9 (see p. 5) suggests that there is a close association in many pupils minds, between energy and friction.

RESULTS AS PERCENTAGES FOR SURVEY QUESTION 9

	3rd form (N = 255)	4th form (N = 198)	5th form (N = 176)	6th form (N = 147)	7th form (N = 75)
a	27	38	68	77	85
b	68	59	32	23	15
c	3	2	1	-	-
d	3	1	-	-	-

(e) Friction and Solids, Liquids and Gases

Twelve of the pupils interviewed considered that friction was associated with the rubbing together of only solid objects (3 x F2, 4 x F3, 4 x F4, F6) while others considered friction could occur with liquids but not in air (3 x F2, F3, 3 x F4, 2 x F5, F6). For example,

> "You can't really have friction between something like water and air, and that sort of stuff."
> (F4)

> "Um ... I'm not sure really. The water ... oh ... the water isn't actually a ... the water isn't .. um ... it's only ... the water isn't actually one surface, is it? Yeah, one solid surface ... where the body is ... um ... I'm not very sure about that one."
> (F6)

This sixth form pupil was obviously wrestling with the contradiction that, although there was present an opposing force on a swimmer as he moved through the water, the water itself is not solid and, for this student, friction occurred only between two solid objects.

The Survey questions 10-12 (see p. 5) and the responses obtained to the questions indicate the relative prevalence of the sorts of views mentioned in this section.

RESULTS AS PERCENTAGES FOR SURVEY QUESTIONS 10-12

	3rd form (N = 255)	4th form (N = 201)	5th form (N = 177)	6th form (N = 146)	7th form (N = 75)
aaa	22	17	15	10	7
abb	18	17	12	4	-
aaa	40	59	66	77	85
aba	9	3	4	2	3
baa	4	1	3	2	5
other	6	3	2	4	-

The contrast between children's views on friction and the scientists' views are summarised in Part 2.2.

PART 5: GRAVITY

5.1 The Scientific View of Gravity

Gravity is a term not defined in Physics.[20] In science lessons the term is frequently used as an abbreviation for 'force of gravity' or 'force of gravity per unit mass'.

The exact nature of the gravitational attraction is unknown. However the strength of attraction between any two masses depends only on the sizes of the masses and on their distance apart. It does not depend on the nature of the medium (e.g. air or vacuum) between the masses.

The most familiar example of gravity is the earth's gravitational attraction. The gravitational attraction exerted by the earth on an object is always toward the earth's centre, and both above and below the earth's surface this attraction is less that at the earth's surface. Below the earth's surface, the strength of the pull of gravity is proportional to the distance from the earth's centre. Above the earth's surface the pull of gravity is inversely proportional to the square of the distance from the centre of the earth.[21] While the gravitational force always acts on objects at the earth's surface, other forces, e.g. reaction or buoyancy, are also usually present so that the total force on stationary objects is indeed zero.

Because gravitational attraction occurs even if there is a vacuum between the objects, there is an attraction between the earth and the moon, between the earth and satellites which are beyond the atmosphere,

---

20 From a scientific point of view, 'gravity' on its own has little meaning. It takes on very specific meanings when used with other terms, as in gravitational force, gravitational field (a region in which objects with mass experience a force) and gravitational field strength (the size of the gravitational force between a 1 kg mass and say, earth).

21 From this information it can be shown that near the earth's surface the pull of gravity is practically constant with height - within 1% of the value at the earth's surface from 32 km above the earth's surface to 64 km below the earth's surface.

and there is an attraction between the moon and objects on, or near, the moon.

The force of gravity between two objects is normally quite independent of whether or not the two objects are spinning. For example the fact that the earth is spinning has no real effect on the gravitational attraction between the earth and the moon.

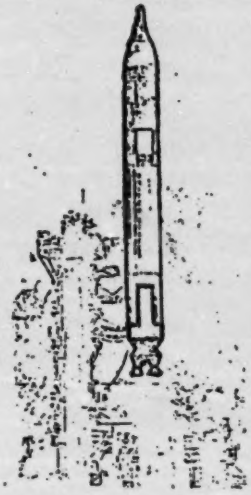
5.2 Children's Views About Gravity

Information on children's ideas was obtained using individual interview methods and a set of 10 illustrations each mounted on a separate card (see Figure 2) to provide a focus to discussion about the idea GRAVITY. [22]

Each picture depicted a single situation where gravity may, or may not, occur.

Card No.3

Card No.5



Card No.8

Figure 1: Three of the cards used in the interviews

22 42 students were interviewed ranging from Form 1 to Form 5 (7 x F1, 8 x F2, 12 x F3, 11 x F4, 4 x F5) from six different schools.

(a) Gravity and Force

When explicitly asked "What is gravity? Tell me about it", nine of the 42 pupils interviewed were unable to give any clear statement (3 x F2, 3 x F3, 3 x F4). The most common answer (5 x F1, 2 x F2, 6 x F3, 4 xF4, F5) related to holding, or pulling, people or objects to the ground. For example, "It holds you down", and "It pulls us down". Such answers are compatible with the scientific viewpoint. Six of these 18 students (F2, F3, 2 x F4, 2 x F5) explicitly stated that it was a force.

> "It's a force that holds us down."
> (F3)

> "It's a force exerted by bodies and the further the distance, the less force ... all objects have it and the bigger they are, the more gravity they have."
> (F5)

On the other hand, four students explicitly stated gravity was a push from above (rather than a pull from below). For example,

> "It's pushing down on the earth to keep things down so they won't fly around."
> (F3)

In summary, the 22 of the pupils interviewed had a view of gravity as something that 'holds', 'pushes' or 'pulls', and in that sense was viewed by students as a force. Almost all students tended to consider gravity first and foremost as something that affects us here on the surface of the earth. Survey question 13 (see p. 6) investigated what proportion of students considered gravity to be present at the earth's surface.

PERCENTAGE RESPONSES FOR SURVEY QUESTION 13

	3rd form (N = 257)	4th form (N = 202)	5th form (N = 179)	6th form (N = 146)	7th form (N = 75)
a	94	96	98	99	100
b	6	4	2	1	-

"(Spacemen) have lead weights in their boots ... to keep them down ... 'cos there is no gravity on the moon."
(F1)

"There is no gravity on the moon ... but there is a weight ... they use heavy shoes to weigh him down."
(F5, F6)

(c) Gravity and Reaction Forces

In our study of force we noted that to some students when an object is in free fall there is no force on it; "it just comes down naturally" (p. 16). It was therefore not surprising to find some six students who tended to view gravity as an upward force. For example, in response to our query concerning a springboard diver.

("Would there be any gravity involved?") "Oh, there would be some when he's jumping up and down otherwise he would fall over, but when he dives there is not really 'cos he's falling straight down, it doesn't hold him up or anything."
(F3)

A fifth former clearly showed this idea of gravity as an upwards force;

("What tells you that there is gravity?") "'Cos I'm walking on it." ("You're walking on gravity?") "Yeah." ("And if gravity wasn't there? What would happen to you?") "Probably sink."
(F5)

(d) Gravity and Buoyancy

In the interviews we obtained a variety of views about the presence or otherwise of gravity in water. While the majority of those interviewed considered there was gravity in the water, five (2 x F1, 2 x F3, F4) explicity stated that there was no gravity when you are swimming (see Fig. 2, card no. 5). For example,

"I don't think there really is any 'cos the water is sort of holding him up, he's sort of floating in the water as you swim. ("What happens if he was to swim underwater? There be any gravity?") "I'm not sure. I don't think so 'cos he's holding himself under, he's making himself go under you know."
(F3)

(b) Gravity and Weight

No person who was interviewed distinguished between the pull of gravity on an object, (which physicists call weight) and the pull of gravity per kilogram (which physicists call gravitational field strength). Many pupils used the word gravity to mean the pull of gravity on an object and did appear to see a close relationship between this and weight. For example, a Form 1 pupil on being asked if a large person is affected by gravity more that a small person stated:

> "Well, he'd be heavier because there's more of him that gravity can grab on and pull him down."

Also,

> ("How does weight tie in with gravity?") "Well, the heavier the object is, the more pull the gravity will give."
> (F4)

On the other hand we found pupils who did not associate gravity and weight quite so closely. One illustration depicted a girl pulling up a bucket from a well using a pulley system. The bucket is in mid-air and the interviewee was asked to explain why the bucket drops as the rope is paid out.

> "It could be (due to) the rope but it all depends." ("It all depends on what?") "What you've got in the bucket." ("Oh, I see, okay. Well, let's say we had nothing in the bucket, what would happen then?") "Oh, the gravity would be pulling it down." ("And if we put something in the bucket?") "Weight would be pulling it down."
> (F2 girl)

> "Gravity only affects heavy objects."
> (F5)

Finally, there were students who explicity stated that it was possible to have weight without the presence of gravity. For example,

Three people (F1, F3, F4) explicitly stated that there is <u>less gravity</u> in the water. For example;

> "Yes, gravity ... there is ... it is a bit. Oh, water reduced the gravity. There is still gravity in the water but water must just decrease (it) ... I don't know why."
> (F3)

Five people (F1, F2, F3, F4, F5) were of the view that there was gravity in the water but that it was upward. For example;

> "There might be gravity going through all the water; that might be keeping you on top of the water."
> (F1)

> "(Under the water) it's probably reversed or something."
> (F4)

Survey question 17 (see p. 6) investigated how many students considered there was gravity underwater. Unfortunately, how many of these that gave answer (a) considered gravity to be upwards is unknown.

PERCENTAGE RESPONSES FOR SURVEY QUESTION 17

	3rd form (N = 256)	4th form (N = 198)	5th form (N = 179)	6th form (N = 145)	7th form (N = 75)
a	40	60	63	87	93
b	23	28	29	12	5
c	37	12	8	1	1

(e) <u>Gravity and Height</u>

Consider the following comments made by a fourth former.

> "A space ship going quite fast 'cos of the pull ... the higher it goes, the stronger the gravity is. Therefore it is got to be able to go very fast and to go against the pull of gravity. Oh, it's got to climb quickly."

This same student was able to use an analogy to explain why gravity is much stronger at the extremities of the atmosphere;

> "It's because it's ... sort of like a human actually trying to reach something and the desperate attempts are the strongest."
>
> (F4)

The idea expressed above, that gravity increases with height above the earth's surface, was not an isolated case. Eight people (2 x F1, F2, 2 x F4, 3 x F5) suggested the gravity increased with height because you would fall faster from a greater height. The following discussion was about gravity acting on a person on a slide.

> "It would be stronger at the top ... the gravity would be pulling him down more but if he were at the bottom, it wouldn't move as fast you know." ("So why is the gravity going to be stronger at the top of the slide?") "Because it's got further to come." ("And when he gets to the bottom he stands up ... what's the gravity like then?") "Oh, you know, it's just ... it's normal."
>
> (F5)

Comments such as this one suggest that one reason why gravity is sometimes considered to increase with height is that some people closely associate gravity with movement. This association between gravity and movement is similar to the close association in many children's minds between force and movement (discussed earlier). Conversely to some children if there is no downward movement there is no gravity. For four pupils (2 x F3, 2 x F4) interviewed, a flying bird experiences no gravity. As one pupil stated;

> "(The bird) can go up and stay there."
>
> (F4 boy)

As an indicator of the prevalence of particular views, related to the variation of gravity with height, Survey question 14 (see p. 6) was used.

PERCENTAGE RESPONSE FOR SURVEY QUESTION 14

	3rd form (N = 257)	4th form (N = 200)	5th form (N = 179)	6th form (N = 147)	7th form (N = 74)
a	26	35	41	56	65
b	32	31	38	31	27
c	31	29	20	12	8
d	11	5	1	1	-

(f) Gravity and Air

If one has the view that gravity increases with height then there must be some place where it decreases. This is because many students consider that there is no gravity in space. One student had it all worked out.

> "This planet's (earth) got an atmosphere, it's got a sort of shield, or a shield or something holding the atmosphere down and it causes gravity, and it's just that this planet's got it ... let's go to the moon say, it hasn't got any atmosphere or anything, any sort of ... a barrier of some sort, of atmosphere, or gravity or something like that."
>
> (F3)

Other pupils (3 x F2, F3, 3 x F4, 3 x F5) more directly related gravity to the atmosphere, for example,

> "There's atmosphere at levels, isn't there? And out of our atmosphere after it, as it goes higher, the atmosphere there's only gravity in that atmosphere and yet in space where there's oh, I don't think there's atmosphere in space, is there? So there's no gravity, there has to be atmosphere to have gravity."
>
> (F3)

Others considered gravity to be something in the air (F1, F2, F3). For example,

> "It's something in the air that keeps you down."
>
> (F1)

It is not surprising that students associate gravity with the presence of air. Above the earth, satellites orbit in a 'weightless' environment.[23]

"(Gravity) has no effect on him 'cos he's just weightless."
(F5 boy)

The necessity of a force to keep a satellite in orbit is not appreciated. To many children a man on a spacewalk from a satellite even quite near the earth is out of the atmosphere, out of the gravitational field and just floating free. The prevalence of this view was investigated using Survey question 16 (see p. 6).

PERCENTAGE RESPONSES FOR SURVEY QUESTION 16

	3rd form (N = 253)	4th form (N = 198)	5th form (N = 178)	6th form (N = 147)	7th form (N = 75)
a	19	25	28	57	65
b	81	75	72	43	35

(g) Gravity and Space

As might be expected from the last sub-section, some pupils (3 x F1, F2, 2 x F4) expressed the view that there was no gravity on the moon. For example,

"It's only on earth as much as we know and it's not on the moon, or anywhere like that."
(F1, also 2 x F1)

"Oh, there's gravity on other planets; there's probably gravity on nearly every planet in the galaxy or universe. While not every planet does have gravity, like the moon."
(F4 boy)

23 This is the everyday meaning of the word weightless. From the physicists' view the spaceman only appears weightless. However gravity is pulling on him causing him to orbit the earth rather than move in a straight line and in the sense that gravity acts on him he is not 'truly' weightless. A person free falling toward the earth also appears weightless. However gravity is pulling on the person.

Survey question 15 (see p. 6) was used to investigate the prevalence of this view.

PERCENTAGE RESPONSES FOR SURVEY QUESTION 15

	3rd form (N = 258)	4th form (N = 201)	5th form (N = 179)	6th form (N = 145)	7th form (N = 75)
a	12	7	3	-	-
b	2	3	1	1	-
c	42	67	70	96	96
d	44	24	26	4	4

(h) Gravity and Spinning

One of the most difficult viewpoints to understand was the association in some students' minds between the spinning of the earth and gravity.

> "Gravity is caused by the rotations of the earth because as the earth moves around, it sort of makes a pull and that's why people, or we, don't fall off the earth. I think it's gravity weakening because the earth's slowing down and its rotating."
>
> (F4)

Initially these ideas seemed very strange to us in that intuitively one might think that there would be a tendency for us to get thrown off a spinning earth. However it appears that some pupils know that artificial gravity can be created by spinning and therefore it is just assumed that somehow the earth's gravity is created in the same way.

> "I think that if (the earth) didn't spin, there would be less gravity. Sort of like momentum ..." ("You think momentum perhaps might be involved in some way?") "Yeah." ("Why?") "Well, it's just that certain things that happen ... I had a horse and I had a bucket I used to put feed in the bucket and if you're spinning it around, it'll stay in the bottom even when it's up in the air because of the momentum of the force thats keeping it up there ... it might be sort of the same as the earth's spinning .... it might cause gravity."
>
> (F3)

The whole problem is clarified nicely by a Form 3 pupil:

> "When you swing a bucket over your head, you've got the gravity holds it in, at least that's what I've been told. And I don't know why. I think it's 'cos it really hasn't got a chance to come out, that's what I think anyway 'cos you're swirling it that fast and it really can't come out. It's supposed to be something to do with gravity but I can't see how it can be."
>
> (F3)

The contrast between these views and those held by scientists are found in Part 2.3.

IMPLICATIONS FOR TEACHING

In this paper we have summarized children's views and scientists' views and you have examined your own views about force, friction and gravity. Children hold many ideas about these topics which are different from the physicist's viewpoint. More importantly, as we have tried to show, children can retain their original ideas despite considerable exposure to physics teaching.

We believe that children's non-scientific ideas are not loosely held, isolated misconceptions but are part of a firm and self-consistent viewpoint. Central to this viewpoint is the idea that force is something in a moving body and is in the direction of motion. This idea not only influences notions of force in general but also influences ideas related to friction and gravity. If we wish to modify children's views to make them more scientific then it would appear to us that we need to focus children's attention very clearly on the differences between their views and the scientific viewpoint.

The Learning in Science Physics Action-Research group have attempted to produce teaching activities which are centrally concerned with this approach. These can be found in "Teaching about Force, Suggested Teaching Activities", L.I.S.P. Working Paper No. 34.

APPENDIX A - The Interview Cards on Force

THE INTERVIEW CARDS

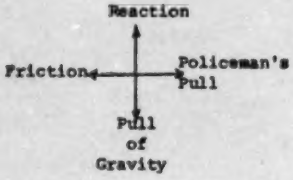
THE PHYSICIST'S VIEW

Individual Forces (direction and strength) | Total (or net) Force

POLICE

A POLICEMAN
MOVING A DEMONSTRATOR

IS THERE A FORCE ON THE DEMONSTRATOR ?

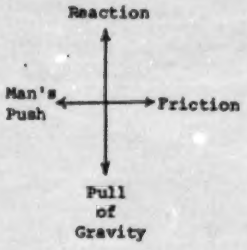


zero (constant speed)

CAR I

THE MAN IS TRYING TO MOVE THE CAR BUT
THE CAR IS NOT MOVING

IS THERE A FORCE ON THE CAR ?



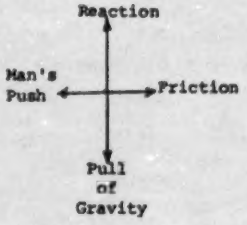
zero (stationary)

CAR II

THE MAN IS TRYING TO MOVE THE CAR
AND THE CAR
IS NOW
MOVING

ENGINE NOT
GOING

IS THERE A FORCE ON THE CAR ?

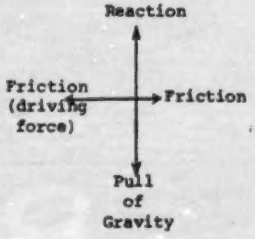


zero (constant speed)

CAR III

THE MINI IS SPEEDING UP
FROM THE TRAFFIC
LIGHTS

IS THERE A FORCE ON THE CAR ?

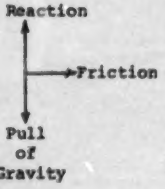


← (accelerating)

BIKE

NO BRAKES
NO PEDALLING
SLOWING DOWN

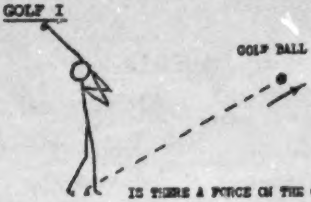
IS THERE A FORCE ON THE BIKE ?



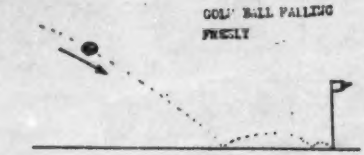
→ (decelerating)

THE INTERVIEW CARDS

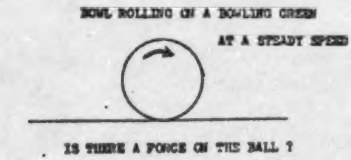
GOLF I



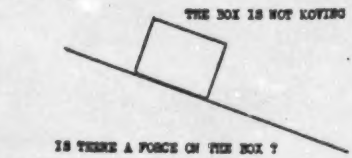
GOLF II



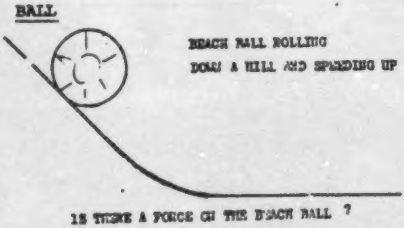
BOWL



BOX



BALL



THE PHYSICIST'S VIEW

	Individual Forces (direction and strength)	Total (or net) Force
GOLF I	Air Friction, Pull of Gravity	(accelerating)
GOLF II	Air Friction, Pull of Gravity	(accelerating)
BOWL	Reaction, Pull of Gravity	zero (steady speed)
BOX	Reaction, Friction, Pull of Gravity	zero (stationary)
BALL	Air Friction, Reaction, Pull of Gravity	(accelerating)

THE INTERVIEW CARDS

THE PHYSICIST'S VIEW

Individual Forces (direction and strength) | Total (or net) Force

CUSHION

IS THERE A FORCE ON THE CUSHION ?

Reaction

Pull of Gravity

zero (stationary)

WEIGHTLIFTER

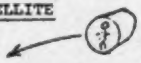
IS THERE A FORCE ON THE BAR ?

Reaction

Pull of Gravity

zero (stationary)

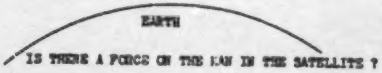
SATELLITE



MAN IN A SATELLITE GOING AROUND THE EARTH

Pull of Gravity

(accelerating)



IS THERE A FORCE ON THE MAN IN THE SATELLITE ?

MOON

MAN STANDING ON THE MOON

IS THERE A FORCE ON THE MAN ?

Reaction

Pull of Gravity

zero (stationary)